Evaluation of the Effect of Uncertainty Expression Method on Material Balance Evaluation for Nuclear Safeguards

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Introduction

- The KINAC has been developing an independent material balance evaluation (MBE) program for national safeguards inspection^[1]
- However, the IAEA's uncertainty expression method for MBE has limitations
- Benchmark MBEs were performed using three different uncertainty expression methods and optimized method was identified

Research Overview

Identifying the measurement system of the facility

Calculating the MUF using general ledger and the LII

Uncertainty Expression Methods



Calculate the MUF uncertainty (σ_{MUF}) using different uncertainty expression methods and evaluate the σ_{MUF}



Identifying the optimized uncertainty expression method

Material Unaccounted for (MUF): Difference between the book and measured inventory List of Inventory Items (LII): List of all items in the facility and its measured information

Benchmark Facility Configuration

- The benchmark **facility** is a **fuel fabrication** process with **2 plants** and **12** key measurement points (KMPs)
 - The facility consists of **reconversion**, **pelletizing**, **rod** ____ insertion and assembling process
 - The facility contains 14,538 items in 15 strata



		Method		-
КМР	Description		1	1

Stratum Description Location Q P T(E) Breaction Paint Storage 1 0 0 0 Breaction Paint Storage 1 1 0 0 0 Breaction Storage Breaction Storage 1 1 0 0 0 Breaction Storage Breaction Storage 1 1 0 0 0 Breaction Storage Breaction Storage Breaction Storage		Plant 1	Plar	nt 2		lable	2. Strata info	rmation and mea	asure	eme	nt sy	ste
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SUP-IL Recon Powder Storage 7 4 3 Laboratory sample TITR TIMS DD 4L H H H H H H H H H H H H H H H H H H H		Liquid waste		-	-	SD-1L	Dirty Scrap	U storage	3	4	3	┢
	+	Laboratory sample		TITR	TIMS	SD-1L	11. 11.	Recon Powder Storage	/	4	3	┣

Results

Conventional IAEA's method

					Meas	s. Inv	vente	ory (l	kg)	Bo	Book Inventory (kg				MUF (kg	g) (σ(MUF) (kg)	Si	gnifica	nce(3o)
	U	J235	Wei	ght	38,572.				.800 38				38,5	,548.731 -24.069			43.546		k.	
	V(MUF,I	sotope)	Vr(M	UF, Isc	otope)	Vg(N	MUF, Iso	tope)		Vs(MUF	-,Isotop	e)		V(MUF	,Isotope)		Vr*(MUF)		Vs*(Ml	JF)
	1101	1101.218 790.957 11.677					298.584				795	5.045		762.572		32.47	3			
	Stratum	Vr(xkq)	Vr(xkp)	Vr(xkt(E))	qpt(E)	Vg(q)	Vg(p)	Vg(t(E))	qpt(E)	Vs(q)	Vs(p)	Vs(t(E))	1	ID	S_1		Vr*(MUF)	t	T_I	Vs*(MUF)
	FF-11 FF-BD	0.02684	0.00000	0.00000	2.00000	0.000	0.000	3.543	2.00000	118.958	0.000	0.000		1		42.465	5.861E-03	1	5380.966	2.895E+01
						~~~~					~~~~			3		0.720	1.685E-06	2	1843.539	3.399E+00
	PD-1L	0.00000	0.00001	0.00000	12.00000	0.000			12.00000	0.000			~~~	$\sim$	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	$\sim$		$\sim$	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
	PD-1L	0.00617	0.99476	0.02072	13.00000	0.000			13.00000	0.000					~~~~~	and		~~~	~~~~	~~~~~
	PL1-L PL1-L	0.00002	0.00000	0.00000	14.00000	0.000			14.00000	0.000		<u> </u>		46	2	244.962	6.002E+02			
	PL2-L	0.00000	0.00017	0.00000	10.0000	0.000			10.00000	0.000			,	47	1	100.477	1.010E+02			
						$\sim$			~~~	~~~	~~~~	~~~~	~							
_	SC-PL	0.00025	31.77216	0.10691		$\sim$			$\sim$	$\sim$	~~~~	$\sim$	$\sim$							
	PL1-L	0.00000	0.00458	0.00002																
	PL1-L	0.00012	0.01420	0.00118	-															
	SD-1L	0.00009	600.06381	0.02000																
	SD-1L	0.00000	0.00000	0.00000	1															
	ODPIL		0.0000	0.00000																
		itati																		

Limitations

- Measurement results of the elemental and isotopic analysis is not independent
- Items in the same stratum are not homogeneous
- Inherent limitations from quantifying the systematic error cannot be managed

#### Modified IAEA's method



#### Limitations

- Measurement results of the elemental and isotopic analysis is not independent
- Items in the same sub-stratum are not homogeneous
- Inherent limitations from quantifying the systematic error cannot be managed

#### ISO standard method (GUM)

	Meas Inventory (kg)	Book Inventory (kg)	MUF (kg)	σ(MUF) (kg)	Significance(3o)
11025 Mainht (1/0)	20 572 000	20 540 724	04.000	10 717	Na

	<u> </u>	200		ngin	. (	- <i>j</i> .			- 50,	512	.000				50,0	40.751	24.000		5.7 1	110
5																				
-	2 6	P 3 1	1(E) 1	1(1)	42.465	0.007									Stratum	١	/*(MUF) (kg^2)	Strat	um	V*(MUF) (kg^2)
. I		Ricet	Location	1100	Batch	Cont. No	Qty	ULot	Gross (KG)	Net (KG)	Uran (%)	Uran (KG)	U235	U235 (KG)	FF-11		0.062	PL1	-L	20.724
ť	MP		Location	MDC 1	r vame			NO V	*	×	~	*	(70)		FF-BD		0.282	PL2	-L	0.233
	C	Plant 1	Powder St	o GQRC	L16	8LM220	1	HO-16N20	474.9	327.1	87.804 87.804	287.207	2.214	6.359	FR-11		0.014	SA-	1L	0.000
	č	Plant 1	Powder St	o GQRC	L16	8LM220	1	HO-16N20	381	232	87.804	203.705	2.214	4.510	FR-1G		0.002	SA	1	0.000
	c	Plant 1	Powder St	o GQRC	L16	8LM220	_1	HO-16N20	476.7	324.5	87.804	284.924	2.214	6.308	HE-1L		0.000	PM-	1L	0.017
	c	Plant 1	Powder St	o GQRC	L16	8LM220	1	HO-16N20	473.2	323.2	87.804	283.837	2.231	6.332	UF-1L		2.434	SC-	1L	5.439
	~	FIGHT	Under Of	ouno	210	OLM220		10-10120	4/1	515	07.004	200.140	2.201	0.200	PD-1L		6.067	SC-	2	9.591
		• -																SD-	1L	143.284
1	Li	mita	atío	ns																

- The quality of the facilities' measurement system has to be managed with the documented standard processes
- Realistic uncertainty of the GUM method for DA is much bigger than the ITV

### Conclusion

• The three uncertainty expression methods (conventional-modified IAEA's method and ISO standard method) have limitations and the limitations of one method is the advantages of the other methods • The MBE program will adopt ISO standard method since the IAEA's methods limitations cannot be managed

#### References

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